Original Research Article

Evaluation of cervical spine injury and predicting neurological deficit by magnetic resonance imaging

Sushant H Bhadane[1], Sapana S Bhadane[2*]

[1]Associate Professor, Department of Radiology, [2]Assisstant Professor, Department of Pathology, SMBT Institute of Medical Sciences and Research Centre, Dhamangoan, Nashik, Maharashtra, INDIA.
Email: drsushbhadane@gmail.com

Abstract

Background: The consequences of cervical spine injuries range from simple neck pain, to quadriplegia, or even death. MR imaging has become part of the diagnostic and prognostic tools for spinal cord injury. **Aim:** To prospectively evaluate cervical spine injuries by MR imaging and to find out association of MR imaging findings with degree of neurological deficit. **Material and Methods:** Descriptive longitudinal hospital based study was conducted on 30 patients with known or suspected cervical spine trauma who presented to the emergency department. **Results:** Mean age of the cases was about 42 years, with female to male ratio of 1:6.5. C6-C7 spinal level was most commonly involved. Proportions complete spinal cord injury (CSCI), incomplete spinal cord injury (ISCI) and neurologically normal (NN) were 23.33%, 60% and 16.67% respectively. Out of 12 MRI findings, cord haemorrhage, contusion, posterior element fracture, disc injury, prevertebral hematoma, subluxation and soft tissue injury was statistically associated with degree of neurological deficit. Cord contusion, cord haemorrhage and posterior element fracture were potential predictors of neurological status at admission. Cord contusion, cord haemorrhage and subluxation were potential predictors at 3 months. **Conclusion:** MRI proved a pivotal role in the diagnosis of SCIs, deciding prompt management and predicting neurological deficit and prognosis of neurological recovery. So, MRI is an excellent diagnostic modality for the evaluation of spinal trauma and predicting the degree of neurological deficit and recovery.

Key Words: Spinal trauma, American Spine Injury Association score (ASIA), Spinal cord injury, Frankel.

***Address for Correspondence:**
Dr Sapana S. Bhadane, Assistant Professor, Department of Pathology, SMBT Institute of Medical Sciences and Research Centre, Dhamangoan, Nashik, Maharashtra, INDIA
Email: drsushbhadane@gmail.com

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INTRODUCTION

Cervical spine injuries are both common and potentially devastating. According to World Health Organization, between 250000 and 500000 people suffer a spinal cord injury (SCI) around the world, every year.[1] The consequences resulting from neck injuries range from simple neck pain, to quadriplegia, or even death. The initial post-injury period is critical with regard to neurologic recovery or deterioration. The diagnosis of the initial injury is critical in order to predict an accurate functional prognosis.[2,3] Before the advent of MR imaging, there were no imaging methods to assess the severity of traumatic injury to the spinal cord parenchyma.[4] Since early to 1990, MR imaging has become part of the diagnostic and prognostic tools for spinal cord injury.[5] MR imaging provides unparalleled multiplanar depiction of soft tissue injury, including ligament damage, intervertebral disc herniation, spinal cord injury and prevertebral and paravertebral haemorrhage and after blunt cervical spine injuries. It can directly depict the injured segment of the spinal cord and accurately show the extent of macroscopic damage. It also shows the extent of cord damage, edema and swelling which is of prognostic value.[6] The best time for prognostic imaging is

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within the first 24-72 hours of the injury and 2-3 weeks later. [3] Currently MR imaging is the radiological modality of choice in spinal cord injuries to assess the degree of spinal cord damage and possible neurological recovery.[7] The purpose of this study was to prospectively evaluate cervical spine injuries by MR imaging and correlating MR imaging findings with degree of neurological deficit.

MATERIAL AND METHODS

An observational descriptive longitudinal hospital based study was conducted at Kamineni Hospitals, Hyderabad from October 2009 to October 2011. Institutional Ethics Committee permission was taken. Thirty patients with known or suspected cervical spine trauma who presented to the emergency department of hospital and MR study of cervical spine performed within 48 hours of injury and having isolated cervical spinal cord injuries were included. Patients with concomitant head injury and hemodynamically unstable requiring immediate surgical intervention were excluded. Written informed consent was taken from patients or relatives (in case of unconscious patients) before data collection. Information about demographic profile, type and mode of injury, time of injury, date of admission and time of MRI was recorded. The American Spinal Injury Association (ASIA) motor score was used as the neurologic measurement tool and outcome measure at admission and follow-up visits. The ASIA impairment scale was used to classify the severity of SCI by means of assessment of motor and sensory impairments. ASIA grade A indicates complete motor and sensory impairment below the level of injury. ASIA grade B, C and D indicate incomplete SCI with evidence of sacral sensory sparing. Patients with ASIA grade B status have complete motor impairment, whereas those with ASIA grade status have motor function below the level of injury, with a muscle grade lower than 3 (on scale of 1 to 5) on the Medical Research Council scale. Patients with ASIA grade D have motor function below the injury level with key muscle group grade 3 or higher on the Medical Research Council scale ASIA grade E corresponds to no motor or sensory deficit.[8]

MR imaging (procedure and specifications):

MR images were obtained within 24-48 hours after the injury. All patients were examined with use of a close-design standard 1.5 T high field strength MR imaging system (Siemens symphony magnetom, maestro class 1.5T machine). Standardized MR imaging protocols for acutely injured spine were used. T1-weighted images were obtained with an echo time of 10 milliseconds and a pulse repetition time of 590 milliseconds, while T2-weighted images were obtained with echo time of 120 milliseconds and repetition time of 2800 milliseconds. The thickness was 4 mm was used. FOV was 320*320. Both T1 and T2-weighted sagittal and T2-weighted axial imaging were done on all the patients. Gradient recalled echo sequence determine the presence of cord haemorrhage was also performed. Twelve variables indicative of acute cervical spine injury like cord haemorrhage, cord contusion, cord compression, epidural hematoma, vertebral body fracture, posterior element fracture, disc injury, ligament injury, prevertebral hematoma, subluxation, foreign body and vertebral artery thrombosis were assessed and recorded. Data was entered in Microsoft Excel 2007 and analysed by using MedCalc, version 12.1.0.0 software. Comparisons were made among three groups; Complete SCI (CSCI), Incomplete SCI (ISCI) and neurologically normal patients. Descriptive statistics like frequency, proportion and mean was used. Inferential statistics like Chi-square test and stepwise multivariate regression analysis of MR variables was done as potential predictor of admission and 3 months ASIA score. For all Statistical testing, significance was set at 5% level.

RESULTS

Demographic and Injury profile of 30 cases of spinal cord injury is shown in table no. 1. The mean age of the cases was about 42 years, ranging from 22 years to 62 years of age. Proportion of males was more than that of female with female to male ratio of 1:6.5. Out of 30 cases, 13% were females and 87% were males. The C6-C7 spinal level was most commonly involved (30%) followed by C4-C5 and C5-C6 (20% each). The most common mode of injury among 30 patients, motor vehicle accident (60%) was most common followed by fall (40%). Out of total cases, 17 (57%) were not operated and 13 (43%) were operated. Figure no.1, shows severity of spinal cord injury based on American Spinal Injury Association classification (ASIA). Among 30 cases with spinal cord injury (SCI), high proportion of patients had (23.33%) had complete spinal cord injury (CSCI) while an incomplete spinal cord injury (ISCI) was found at the time of admission in 18 cases (60%) and 16.67% cases were neurologically normal (NN). None of the patients who were neurologically normal required surgery. Out of 18 cases with ISCI, 8 (44.44%) underwent surgery while out of 7 patients with CSCI, 5 (71.43%) underwent surgery. Association between various MRI findings in spine injury patients and degree of neurological deficit is shown in table no.2 and figure no.2. Cord contusion (86.67%) was the most common MRI finding seen in patients with cervical spine injury (CSI) followed by cord compression, disc injury, pre vertebral hematoma and subluxation (n=18; 60% each). Epidural hematoma was the least common finding seen only in 2 (6.67%) patients.

Among 7 CSCI cases, all had cord concussion and subluxation (100%); 6 had ligament injury, prevertebral hematoma and soft tissue injury (85.71%); 5 had cord compression and disc injury (71.43%); 4 had cord haemorrhage, post. elemental fracture and vertebral artery thrombosis (57.14%). Among 18 cases of ISCI, all had cord contusion (100%); 13 had disc injury (72.22%); 12 had cord compression (66.67%); 11 had prevertebral hematoma, soft tissue injury (61.11%); 10 had subluxation (55.56%); 7 had ligament injury (38.89%) and rest had vertebral artery thrombosis, post. element fracture, vertebral body fracture and epidural hematoma. Five cases were neurologically normal (NN), who had ligament injury, prevertebral hematoma, subluxation, cord contusion and compression, vertebral body fracture and post. element fracture. Out of these 12 MRI findings found in spinal cord injury cases, 7 were found to be associated with degree of neurological deficit. Association between them was statistically significant. These findings were cord haemorrhage, contusion, post. element fracture, disc injury, prevertebral hematoma, subluxation and soft tissue injury. A stepwise multivariate regression analysis of all seven significant MRI variables as potential predictors of ASIA (American Spinal Injury Association) score at admission and at 3 months was done and reported in table no. 3. The best model for predicting the admission ASIA score (R^2=0.652) included cord contusion ($p<0.0001$), cord haemorrhage ($p=0.034$) and posterior element fracture ($p=0.006$) signifying these factors were main predictors. The best model for predicting ASIA score at 3 months (R^2=0.610) included cord contusion ($p=0.002$), post. element fracture ($p=0.04$) and subluxation ($p=0.002$) signifying these factors were main predictors at 3 months.

Table 1: Demographic and injury profile of study subjects (n=30)

Characteristics		Number of Patients (n= 30)
Age	Mean Age in years	42.07
Gender	Male	26 (87%)
	Female	4 (13%)
Mode of Injury	Motor Vehicle Accident	18 (60%)
	Fall	12 (40%)
Level of SCI	Cl-C2	2 (7%)
	C2-C3	4 (13%)
	C3-C4	3 (10%)
	C4-C5	6 (20%)
	C5-C6	6 (20%)
	C6-C7	9 (30%)
Surgical Status	Operated	13 (43%)
	Not Operated	17 (57%)

Table 2: Association between various MRI findings in spine injury patients and degree of neurological deficit

MRI findings	CSCI (n=7)		ISCI (n=18)		NN (n=5)		Statistical significance
	No.	%	No.	%	No.	%	
Cord Haemorrhage	4	57.14	3	16.67	0	0	Significant
Cord Contusion	7	100	18	100	1	20	Significant
Epidural Hematoma	1	14.29	1	5.55	0	0	Not Significant
Cord Compression	5	71.43	12	66.67	1	20	Not Significant
Vertebral Body Fracture	1	14.29	2	11.11	2	40	Not Significant
Post. Element Fracture	4	57.14	1	5.55	1	20	Significant
Disc Injury	5	71.43	13	72.22	0	0	Significant
Ligament Injury	6	85.71	7	38.89	2	40	Not Significant
Prevertebral Hematoma	6	85.71	11	61.11	1	20	Significant
Subluxation	7	100	10	55.56	1	20	Significant
Soft tissue Injury	6	85.71	11	61.11	0	0	Significant
Vertebral Artery Thrombosis	4	57.14	5	27.78	0	0	Not Significant

Table 3: Result of Stepwise Multivariate Regression Analysis of MR variables as potential predictors of admission and 3 months ASIA score

Prediction model no.	R2	Dependent variable	Independent Variables	P value
1	0.652	ASIA Score on admission	Cord Contusion	<0.0001
			Cord Hemorrhage	0.034
			Disc Injury	>0.05
			Posterior Element fracture	0.006
			Pre vertebral Hematoma	>0.05
			Subluxation	>0.05
			Soft Tissue Injury	>0.05
2	0.61	ASIA Score at 3 months adjusted*	Cord Contusion	0.002
			Cord Hemorrhage	>0.05
			Disc Injury	>0.05
			Posterior Element fracture	0.04
			Pre vertebral Hematoma	>0.05
			Subluxation	0.002
			Soft Tissue Injury	>0.05

* Last observation carried forward (LOCF) for 8 patients (6 Expired + 2 Lost to follow-up)

DISCUSSION

Previously the Frankel classification[9] has been the only method to determine the neurological status and possible recovery of patients after SCI. The use of MRI is now well established as the method of choice in examining patients with SCI, and correlating it with their neurological status and using it as a possible predictor of neurological recovery. [10] Although CT scan is superior in detecting precise bony injuries, MRI is most sensitive modality for detecting SCI, disc protrusion and para-spinal soft tissue injuries. The diagnosis of the initial injury is critical in order to predict an accurate functional prognosis. [10,11] In study done by Miyanji *et al*[12], male to female ratio was 3.76:1; mean age of patients was 45 years; motor vehicle was most common mechanism of injury; C5-C6 was most common spinal level of injury and most common neurological status on admission was ISCI in 51% cases. In study done by M ter Haar *et al*[13], male to female ratio was 6.69:1; mean age of patients was 37 years; motor vehicle was most common mechanism of injury; C5-C6 was most common spinal level of injury and most common neurological status on admission was ISCI in 44% cases. Present study findings were comparable with previous two studies by Miyanji *et al*[12] and M ter Haar[13] and colleagues except for the most common spinal level of injury which was C5-C6 in their studies and C6-C7 in our study. Bondurant *et al*[14] reported that type I lesions (a region of decreased signal intensity, consistent with intra-spinal haemorrhage) represent the most severe form of SCI (ASIA grade A). The type II (a region of high signal intensity, representing cord edema) and type III (region of hypo-intensity mixed with a peripheral region of high signal intensity, consistent with contusion) abnormality patterns were seen in patients with incomplete injuries or in neurologically healthy subjects and these patients showed neurologic improvement over time. In current study, the patients who had cord contusion along with subluxation, prevertebral hematoma and ligament injury had poor outcome. Study done by Miyanji *et al*[12] reported cord haemorrhage, cord contusion and soft tissue injury were associated with neurological deficit while M ter Haar *et al*[13] reported cord contusion and haemorrhage were associated statistically with neurological deficit. So these findings were slightly different from current study findings. In previous studies by Flanders *et al*[4] and M ter Haar[13] and colleagues did not find an association between soft tissue injury and extent of SCI, But a study by Miyanji *et al*[12] found a significant difference in three groups, with complete ASIA grade A injuries involving more associated soft tissue injuries. Tewari *et al*[15] also found MR imaging to have diagnostic and prognostic value in the setting of SCI. They found patients with minimal cord changes at MR imaging to have the best outcomes and patients with cord contusion to hand the next best outcomes Patients with haemorrhage and contusion had the worst outcomes. The presence of spinal cord haemorrhage on MRI represents the most severe form of spinal cord damage and is associated with very poor neurological function. These patients are more likely to have complete SCI. Some authors differ in this regard and showed that although the presence of cord haemorrhage was associated with a high degree of complete SCI and a poor prognosis in terms of neurological recovery the presence of haemorrhage does not always imply complete SCI without the possibility of any recovery. [5] These authors agree that the size of the haemorrhage influence the severity of SCI. The presence of a small area of haemorrhage is often associated with incomplete SCI. Liao *et al*[16] found MR imaging patterns to have substantial prognostic correlations with neurologic outcomes. They reported normal spinal cord appearance was prognostic of complete recovery, and intramedullary lesions correlated with permanent deficits and functional disability. Ishida and Tominaga *et al*[17] assessed predictors of neurologic recovery in patients with acute central cervical SCI and found absence of MR signal intensity in the spinal cord and good early neurologic improvement to be important predictors of long-term improvement of neurologic function. In a study by Miyanji *et al*[12] they found that, the best model for predicting the baseline ASIA motor score included maximum canal compromise, maximum spinal cord compression, and cord swelling as significant covariates. The best model for predicting unadjusted follow-up neurologic outcome included maximum spinal cord compression, intramedullary haemorrhage, and cord swelling. After controlling for the baseline ASIA motor score, the best model for predicting the follow-up ASIA motor score adjusted for baseline ASIA motor score included only intramedullary haemorrhage and cord swelling. In a similar study done by M ter Haar and colleagues[13] found that, the best predictors of baseline Frankel grading were the length of lesion and presence of intramedullary haemorrhage. Both were negatively associated with the Frankel grading score, thus they were associated with poorer Frankel grading scores. The best model for predicting Frankel grading at follow-up was maximum spinal cord compression, length of lesion and intramedullary haemorrhage. These variables also predicted poorer Frankel scores at discharge as they were negatively associated with the outcome. In current study, the best model for predicting the admission ASIA included cord contusion, cord haemorrhage and posterior element fracture. The best model for predicting the adjusted ASIA score at 3 months follow-up included cord contusion, posterior element fracture and subluxation. All variables were negatively associated with the ASIA score, thus they were associated with poorer ASIA scores.

CONCLUSION

In current study, MRI proved a pivotal role in the diagnosis of SCIs, deciding timely and prompt management and predicting neurological deficit and prognosis of neurological recovery. Cord contusion, cord haemorrhage and posterior element fracture were potential predictors of neurological status at admission. Cord contusion, cord haemorrhage and subluxation were potential predictors at 3 months. Disc injury, soft tissue injury and prevertebral hematoma had no major implication in predicting the neurological status of patients. So, MRI is an excellent diagnostic modality for the evaluation of spinal trauma and predicting the degree of neurological deficit and recovery.

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